



# Building Safe and Secure Systems with AADL

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# Agenda

**Introduction to AADL**

**AADL modeling patterns for safety and security**

**AADL validation tools dedicated to security and safety**

**Demonstration**



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# Introduction

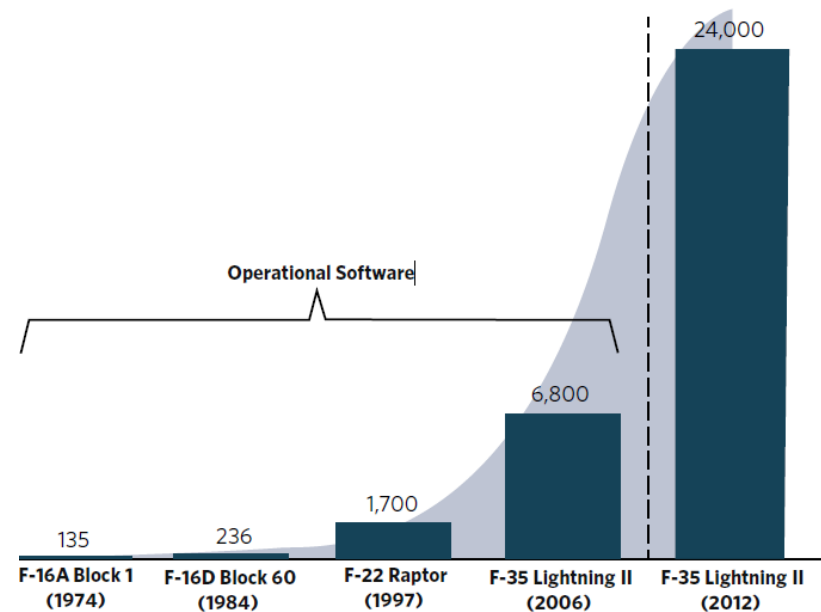
**Systems are becoming extremely software-reliant**

## **Need to verify and validate requirements**

- Requirements errors propagate through design
- Need to verify/validate requirements

## **Major integration and coding issues**

- Incur massive re-engineering rework
- Could be removed by early analysis



# Architecture Analysis and Design Language

## Model-Based Engineering with AADL

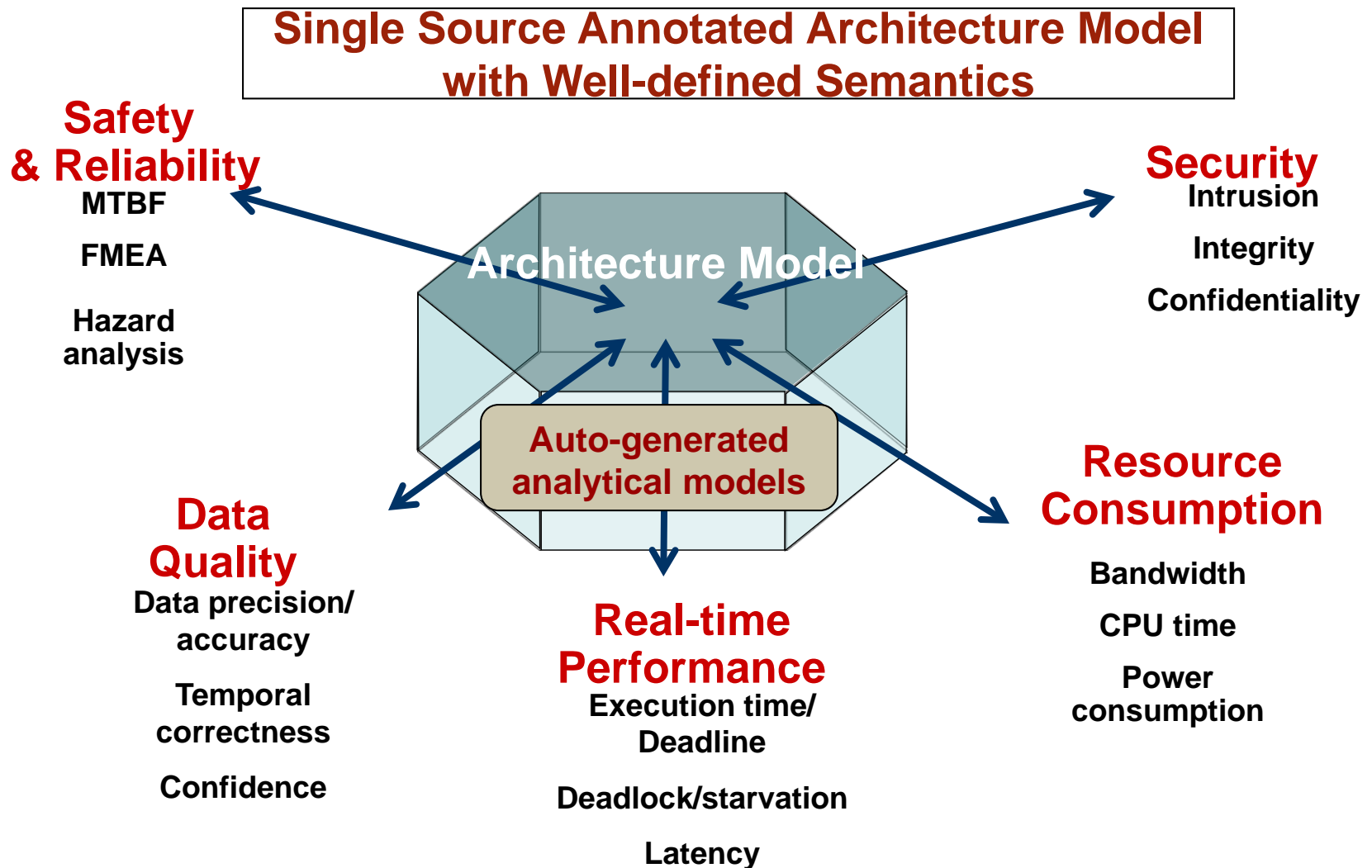
- Architecture Language Description standardized by SAE
- Description of Systems and Software Concerns
- Precise & unambiguous semantics
- Textual and Graphical Representation

## Support for Model Analysis

- Verify system requirements (i.e. latency, safety)
- Check model integration before producing the implementation

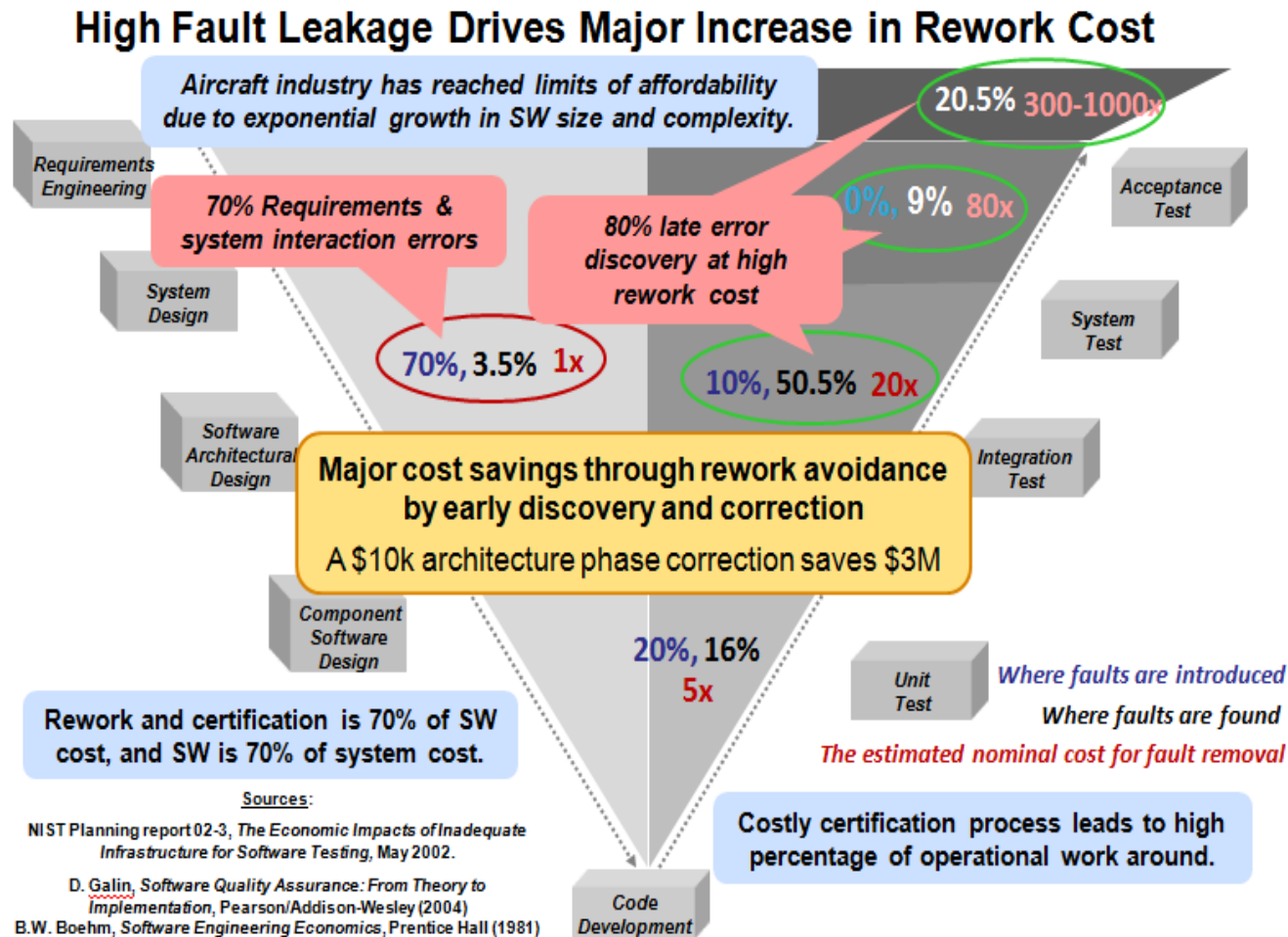


# AADL Model-Based Technology Overview





# Understanding Actual Software Issues



# Use of AADL in Development Process

## Software and Component Design

- Define components requirements & interfaces

- Early verification validation of components integration

## Code Development

- Auto-Generate Code (AADL, Simulink, SCADE)

- Avoid traditional coding errors

- Ensure correct translation of requirements

## Unit & Integration Test

- Automatic generation of tests from models

- Reduce tests as system was validated earlier



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# Security Specifications

## Leverage AADL properties for security level specification

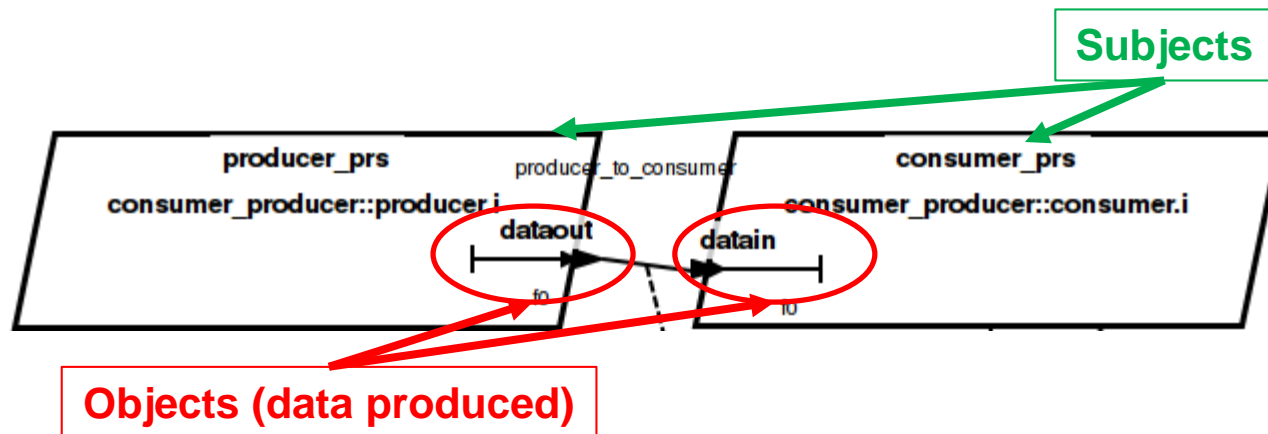
Define security-specific values

Associate them with components and interfaces

## Direct mapping to MILS Security Level concepts

MILS subjects to AADL runtime components

MILS objects to AADL interfaces



# Partitioning Policy (as in ARINC653 or MILS)

## Partitions content and attributes

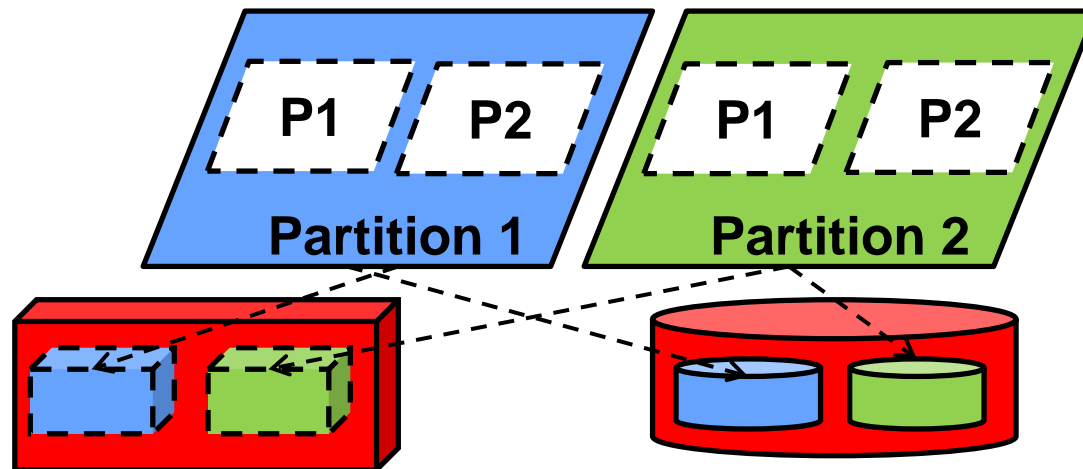
Use the regular process component

Include partition resources (tasks, data, etc.)

## Time and Space Isolation

Time: Partition execution slots

Space: Association of partitions to memory segments

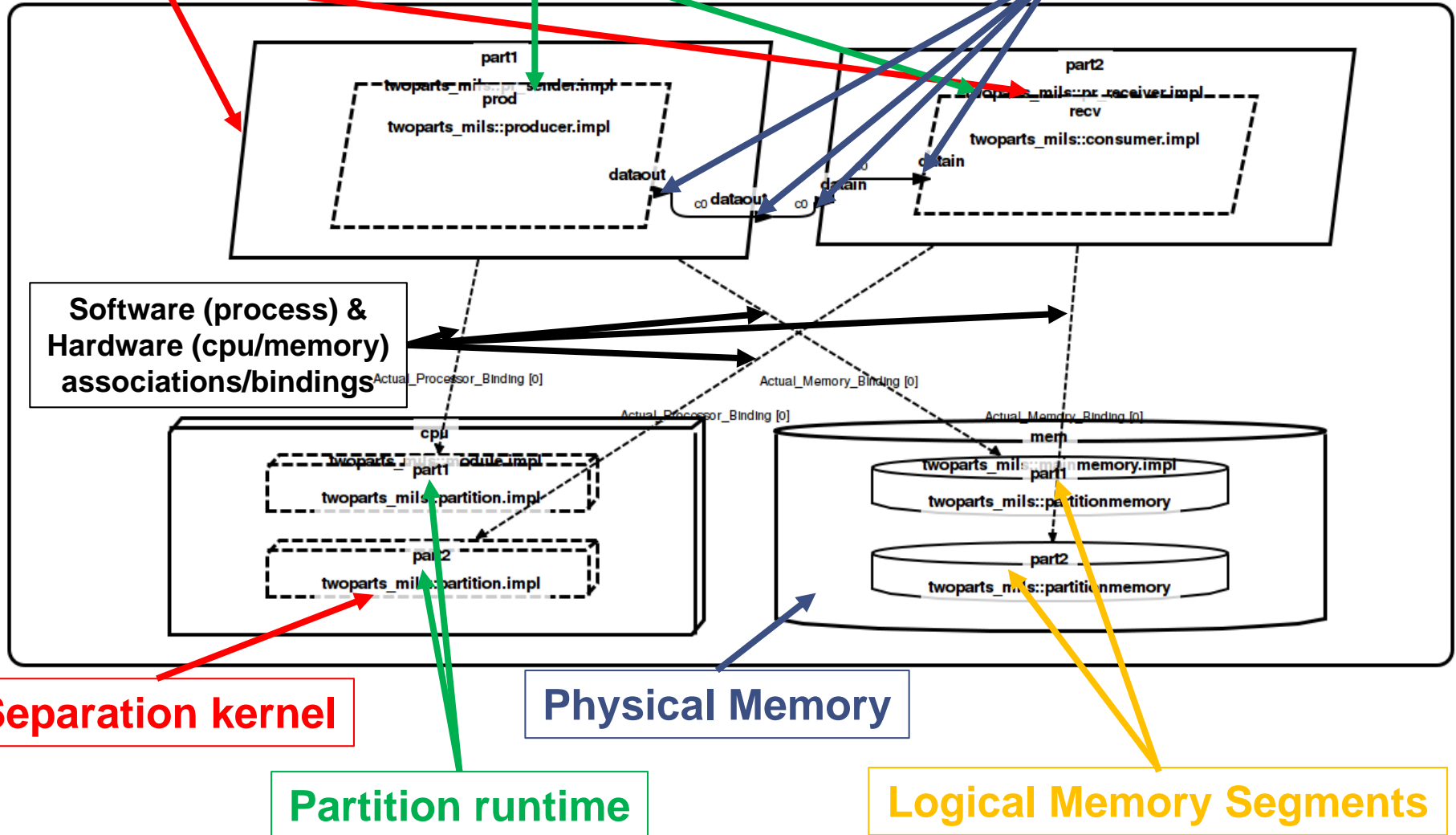


# Modeling a MILS architecture - example

**Partition Content**

**Tasks**

**Software interfaces and data flows**



**Separation kernel**

**Physical Memory**

**Partition runtime**

**Logical Memory Segments**

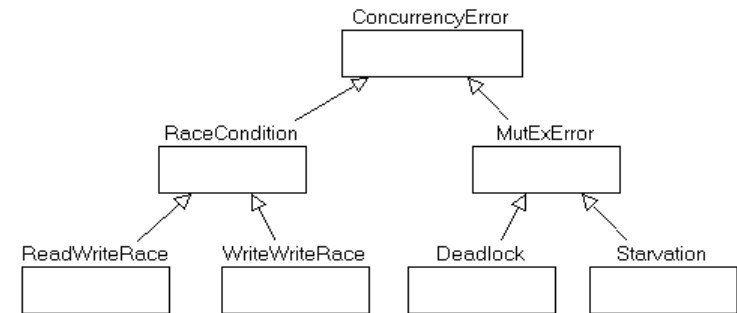


# Safety Policy with the Error-Model Annex V2

## Standardized AADL annex dedicated for safety specification

Integrated with AADL-core

Extend/refine existing models



## Support of Error Types Ontology

Characterize the error (i.e. divide by zero, late value)

Types hierarchy (i.e. late value is an extension of a timing error)

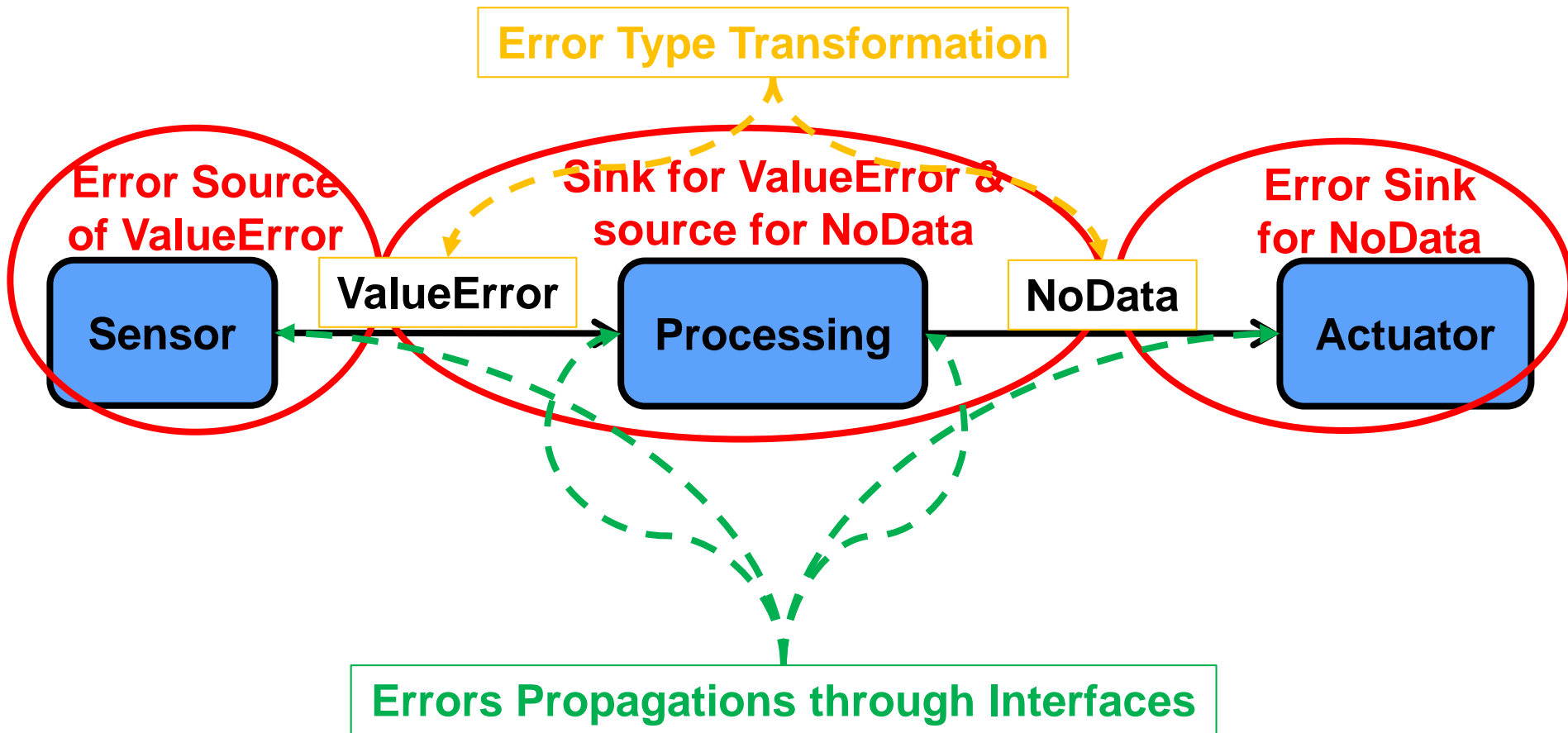
## Error Propagations and Behavior Specification

Errors being propagated by AADL components

Behavior based on external interfaces or sub-components

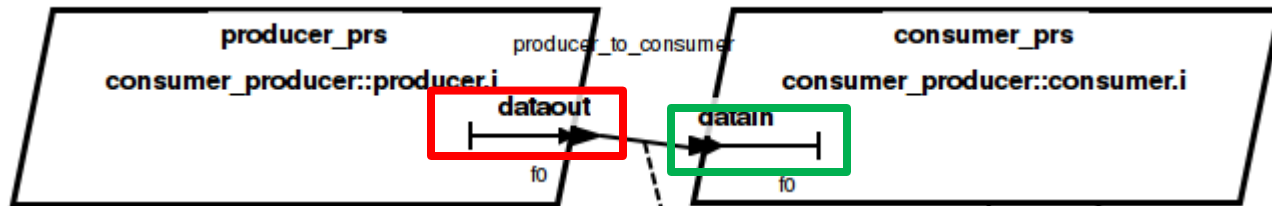


# Error Propagation





# Error Propagation Example



```

thread producer
features
  dataout : out data port Character;
annex EMV2 {**
  use types errorlibrary;
  use behavior errorlibrary::FailAndRecover;
  error propagations
    dataout : out propagation {ValueError};
  flows
    f0 : error source dataout {ValueError};
  end propagations;

  component error behavior
  events
    ComputationError : error event;
  transitions
    t0 : Operational -[ComputationError]-> Failed;
  propagations
    p0 : Failed -[]-> dataout{ValueError};
  end component;

```

```

thread consumer
features
  datain : in data port Character;
annex EMV2 {**
  use types errorlibrary;
  use behavior errorlibrary::FailAndRecover;
  error propagations
    datain : in propagation {ValueError};
  flows
    f0 : error sink datain {ValueError};
  end propagations;

  component error behavior
  transitions
    t0 : Operational -[datain{ValueError}]-> Failed;
  end component;
  properties
    EMV2::severity => ARP4761::Hazardous applies to datain.ValueError;
  **};
end consumer;

```

```

properties
  EMV2::severity => ARP4761::Hazardous applies to dataout.ValueError;
  EMV2::OccurrenceDistribution => [ ProbabilityValue => 1.42e-5 ; Distribution => Poisson; ]
    applies to dataout.ValueError;
  EMV2::likelihood => ARP4761::Probable applies to dataout.ValueError;
  EMV2::hazards =>
    ([ crossreference => "TBD";
      failure => "";
      phases => ("all");
      description => "Bad Value from the thread producer";
      comment => "Must check the software that the value is not faulty";
    ])
    applies to dataout.ValueError;

```



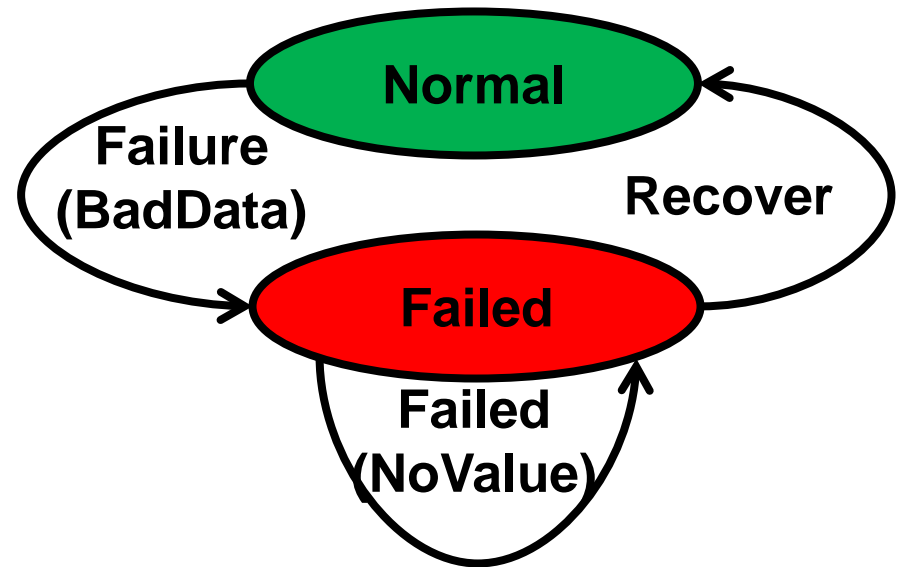
# Error behavior

States machines

Error-related transitions

Propagation rules

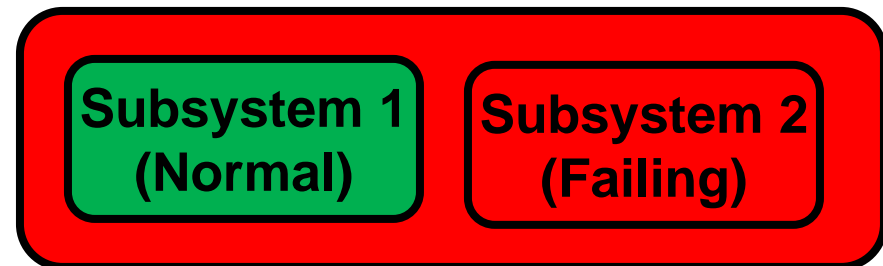
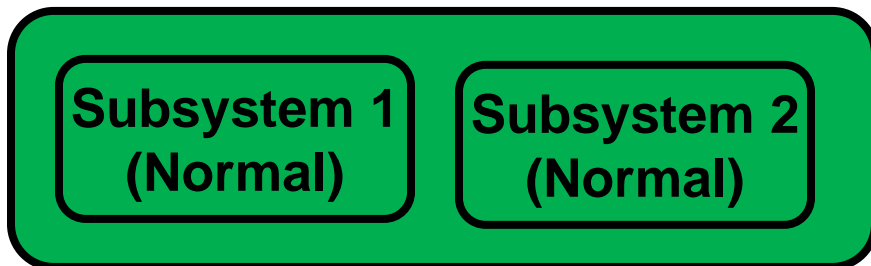
Use of error types



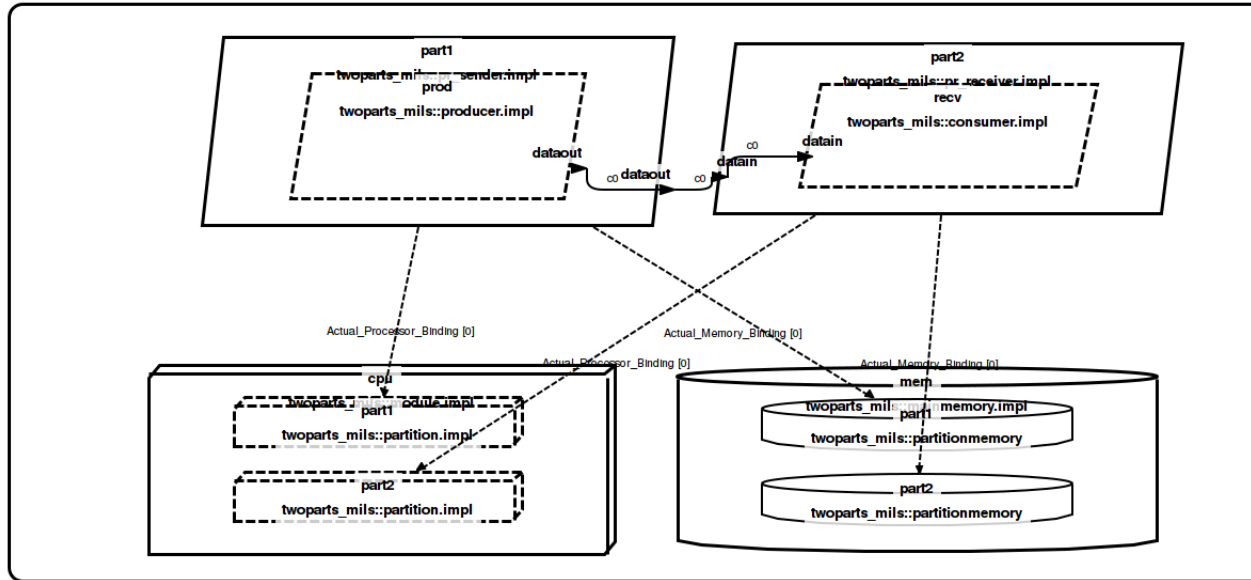
Composite behavior

Define system states according to its parts

*ex: "I am failing if one of my component is failing"*



# Error behavior example



```

cpu.part1)) applies to part1;
cpu.part2)) applies to part2;

t1;
t2;

```

```

-- annex test suite {
--   prove (check_deos_compliance(this))
--   prove (check_mils_compliance(this))
-- };
annex EMV2 {
  use types errorlibrary;
  use behavior errorlibrary::FailAndRecover;

  composite error behavior
  states
    [part1.Failed]-> Failed;
    [part2.Failed]-> Failed;
    [cpu.Failed]-> Failed;
  end composite;
};
end node.impl;

```



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# Security Policy Verification

## Component integration and composition

Partitions share the same level with their tasks

Partitions contain objects at the same level

## Runtime issues

Each process is isolated in a partition

Partitions has at least one execution slot

Memory segments contain partitions at the same security level

## Communication Policies

Communication share the same level

A shared device manages objects at the same level



# Specifying Validation Rules with RESOLUTE

## Specify constraints on the AADL model

Check model consistency and properties

Validation at model level, avoid propagation of errors

## List of rules and functions to check the model

Select elements to be verified

Filter them according to your constraints

Check components characteristics

Select process, connections & virtual processor elements

```
check_mils_partitions_connections (s : system) <=
  ** "Check that connected partitions in " s " share the same security level" **
  forall (p1 : process) (p2 : process) (c : connection) (vp1 : virtual_processor) (vp2 : virtual_processor) .
    (connected (p1, c, p2)) and (processor_bound (p1, vp1)) and (processor_bound (p2, vp2))
  => property (vp1::SEI::SecurityLevel) = property (vp2, SEI::SecurityLevel)
```

Filter connected partitions  
with their associated runtime

Check the runtime security  
level is equal

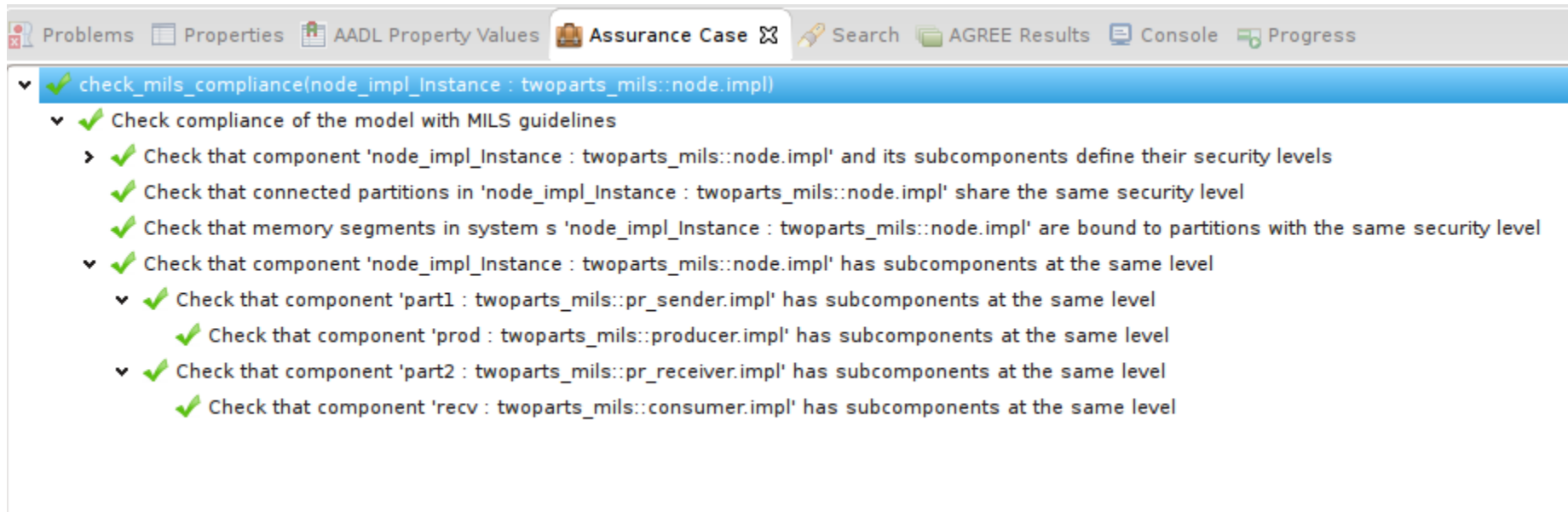


# Generating Assurance Cases

Generate assurance-cases using RESOLUTE and AADL

Show constraints dependencies

Export to Certware



The screenshot displays the Assurance Case tool interface. The top toolbar includes tabs for Problems, Properties, AADL Property Values, Assurance Case (active), Search, AGREE Results, Console, and Progress. The main area shows a tree structure of assurance cases:

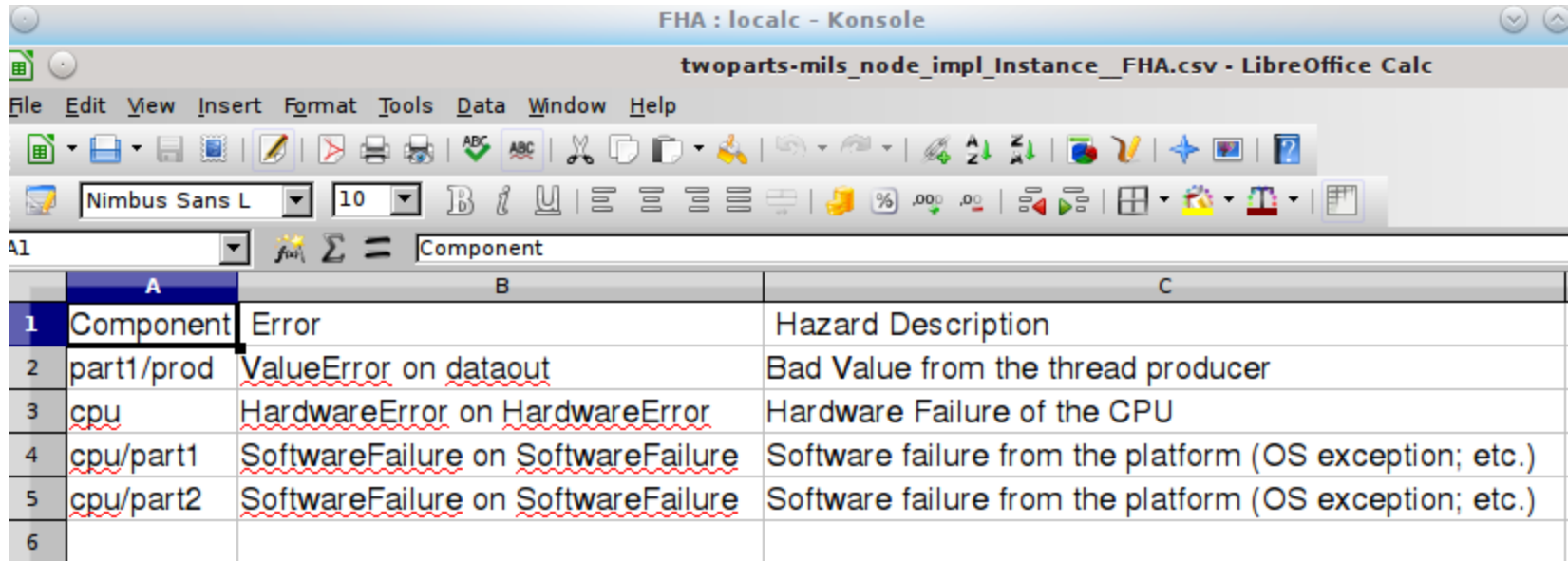
- ▼ check\_mils\_compliance(node\_impl\_Instance : twoparts\_mils::node.impl)
  - ▼ Check compliance of the model with MILS guidelines
    - Check that component 'node\_impl\_Instance : twoparts\_mils::node.impl' and its subcomponents define their security levels
    - Check that connected partitions in 'node\_impl\_Instance : twoparts\_mils::node.impl' share the same security level
    - Check that memory segments in system s 'node\_impl\_Instance : twoparts\_mils::node.impl' are bound to partitions with the same security level
  - ▼ Check that component 'node\_impl\_Instance : twoparts\_mils::node.impl' has subcomponents at the same level
    - ▼ Check that component 'part1 : twoparts\_mils::pr\_sender.impl' has subcomponents at the same level
      - Check that component 'prod : twoparts\_mils::producer.impl' has subcomponents at the same level
    - ▼ Check that component 'part2 : twoparts\_mils::pr\_receiver.impl' has subcomponents at the same level
      - Check that component 'recv : twoparts\_mils::consumer.impl' has subcomponents at the same level



# Safety documentation Generation - FHA

## Functional Hazard Assessment

List of all error sources of the system



	A	B	C
1	Component	Error	Hazard Description
2	part1/prod	<u>ValueError on dataout</u>	Bad Value from the thread producer
3	cpu	<u>HardwareError on HardwareError</u>	Hardware Failure of the CPU
4	cpu/part1	<u>SoftwareFailure on SoftwareFailure</u>	Software failure from the platform (OS exception; etc.)
5	cpu/part2	<u>SoftwareFailure on SoftwareFailure</u>	Software failure from the platform (OS exception; etc.)
6			



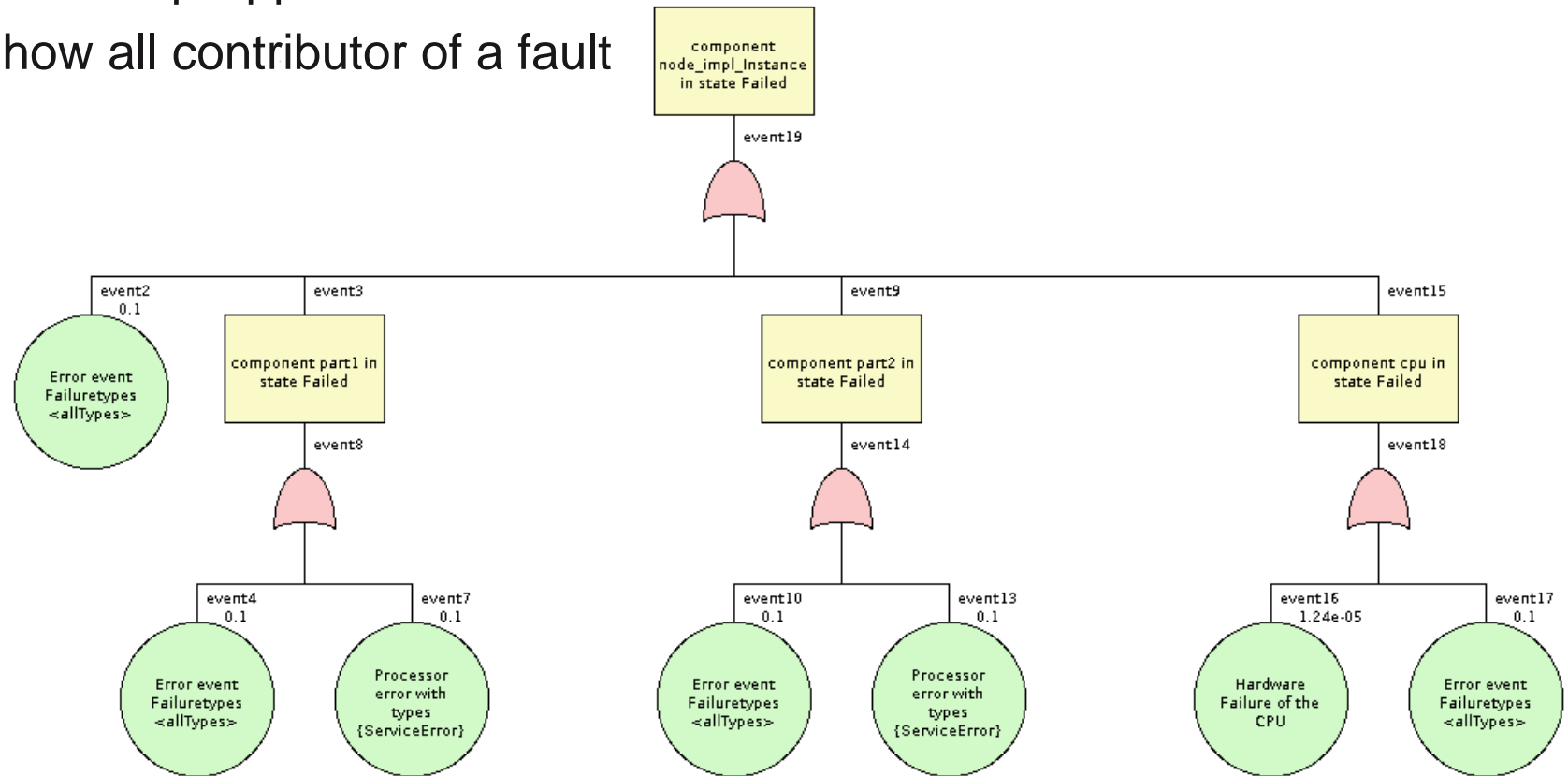


# Safety documentation Generation - FTA

## Fault-Tree Analysis

Bottom-up Approach

Show all contributor of a fault

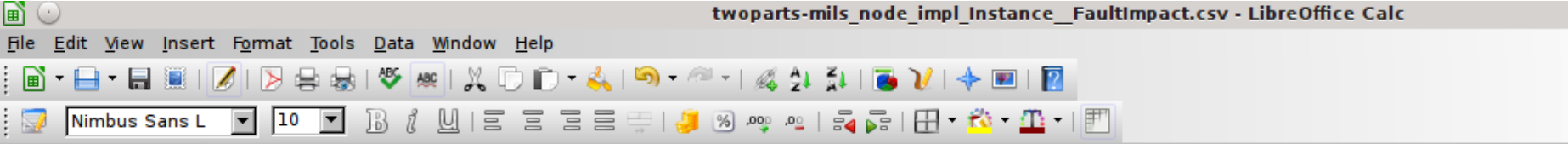


# Safety documentation Generation – Fault Impact

## Failure Mode and Effect Analysis

Propagation paths of failures

Highlight failure containment



twoparts-mils\_node\_impl\_Instance\_FaultImpact.csv - LibreOffice Calc

	A	B	C	D	E	F
1						
2						
3	<b>Component</b>	<b>Initial Failure Mode</b>	<b>1st Level Effect</b>	<b>Failure Mode</b>	<b>second Level Effect</b>	<b>Failure Mode</b>
4	part1.prod	{ValueError}	{ValueError} dataout -> part2.recv: datain	part2.recv {ValueError} [Masked]		
5	cpu.part1	{ServiceError}	{ServiceError} bindings -> part1:processor	part1 {ServiceError}	{ValueError} dataout -> part2.recv {ValueError} [Masked]	
6	cpu.part2	internal event Fail	{ItemOmission} bindings -> part2:processor	part2 {ItemOmission} [Failure Effect]		
7	cpu.part2	internal event Soft	{LateServiceTermination} bindings -> part2:processor	part2 {LateServiceTermination} [Failure Effect]		
8	cpu.part2	{ServiceError}	{ServiceError} bindings -> part2:processor	part2 {ServiceError} [Failure Effect]		
9						



# Automatic Code Generation

## **Automatically produce system implementation**

Ensure implementation of system requirements

Avoid traditional mistakes of manual code generation

## **Low overhead (memory footprint and additional CPU time)**

Less than 10% in memory and computation increase

Benefits outweigh the potential

## **Support for different runtime**

ARINC653/MILS – focus on safety/security (DeOS, POK)

POSIX (RTEMS, Linux)



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# Conclusion

## **AADL flexible language to define safety and security concerns**

Early verification, reducing tests and integration costs

Automatic code production, avoiding code and integration mistakes

## **Integration with existing development methods**

Safety documentation (i.e. ARP4761)

Coding standards (i.e. ARINC653)

## **Bridge with Validation and Assurance Case tools**

Check model consistency and composition

Auto-Generate assurance cases from models



# Links & Useful Information

AADL website – <http://www.aadl.info>

AADL wiki – <http://www.aadl.info/wiki>

ARINC653 AADL annex standard - <http://standards.sae.org/as5506/2/>



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